DOCUMENT RESUME

ED 252 414 SE 045 336

AUTHOR Nelson, David
TITLE Oxidation Ditches. Student Manual. Biological Treatment Process Control.
INSTITUTION Linn-Benton Community Coll., Albany, Oreg.
SPONS AGENCY Environmental Protection Agency, Washington, D. C.
PUB DATE 84
GRANT EPA-T901238
NOTE 60p.; For related documents, see SE 045 333-354.
AVAILABLE FROM Linn-Benton Community College, 6500 S.W. Pacific Blvd., Albany, OR 97321.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

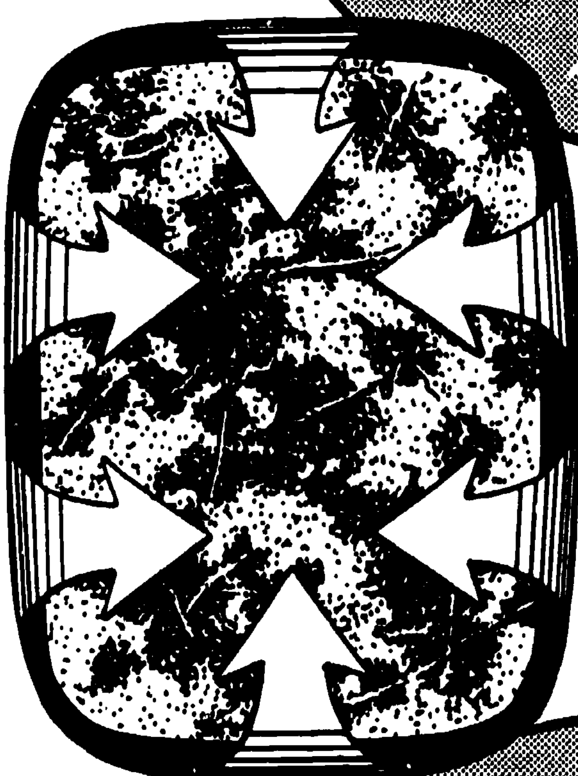
EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Biology; Laboratory Procedures; Microbiology; *Oxidation; Post Secondary Education; *Sludge; *Training Methods; Waste Disposal; *Waste Water; *Water Treatment
IDENTIFIERS *Oxidation Ditches; Unit Processes

ABSTRACT

The textual material for a two-lesson unit on oxidation ditches is presented in this student manual. Topics discussed in the first lesson (introduction, theory, and components) include: history of the oxidation ditch process; various designs of the oxidation ditch; multi-trench systems; carrousel system; advantages and disadvantages of the oxidation ditch; aeration of the oxidation ditch; types of aeration used; safety covers for aerator units; clarification; philosophy of clarification; characteristics of sludge settling; mechanical aspects of clarification; role of sludge settling in clarification; solids inventory controls; importance of segmented wasting schedules; and process hints for the oxidation ditch plant. Topics discussed in the second lesson (process kinetics and process control) include: carbon in the environment; carbonaceous oxidation; process control of carbonaceous oxidation; nitrogen and sewage treatment; importance and sources of nitrogen in the environment; concerns with nitrogen; nitrification/denitrification; process control of carbonaceous and nitrogen oxidation; denitrification kinetics; and helpful hints in the operational control of an oxidation ditch. A list of 21 unit objectives, a glossary of key terms, a short list of references, and student worksheet are included. (JN)

Biological Treatment Process Control

Oxidation Ditches



Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL TREATMENT PROCESS CONTROL

OXIDATION DITCHES

STUDENT MANUAL

Text Written By:
David Nelsen
Envirotech Operating Service
San Mateo, California

Edited By:
John W. Carnegie, Ph.D.
Project Director
Linn-Benton Community College
Albany, Oregon

Instructional Design:
Priscilla Hardin, Ph.D.
Priscilla Hardin Instructional Services
Corvallis, Oregon

Developed Under:
EPA Grant #T901238
1984

OXIDATION DITCHES

Student Manual

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OXIDATION DITCHES

Objectives

Upon completion of this lesson you should be able to:

1. Describe the basic philosophy behind the development of the Oxidation Ditch.
2. State three reasons why the role of the Oxidation Ditch has expanded.
3. Describe the basic design of the system.
4. Name two ways the design of the Oxidation Ditch has evolved to meet the needs of larger users.
5. Describe Multi Trench and Carrousel systems.
6. Name four advantages or disadvantages of the Oxidation Ditch process.
7. Give two important functions of aeration in the Oxidation Ditch process.
8. Name several factors which influence the oxygen requirements of a plant.
9. State the basic philosophy of clarification in an Oxidation Ditch plant and name two ways in which it is accomplished.
10. Describe the importance of sludge quality in settling.
11. Describe the importance of solid inventorying and wasting are to the Oxidation Ditch process.
12. Define SRT and give its importance to plant operation.
13. Give the three basic functions of an Oxidation Ditch process, i.e., carbonaceous oxidation, nitrification, denitrification.
14. Describe five concerns with nitrogen in a treatment plant and the environment; biostimulation, toxic properties, interference with disinfection, pH reduction, D.O. demand.
15. Define nitrification.
16. Define denitrification.

17. Describe the effects of dissolved oxygen, solids retention time, pH, toxic metals and temperature on the control of the oxidation process.

18. Understand the general denitrification kinetics of an Oxidation Ditch plant.

19. Define "anoxic zone" and state its importance to the denitrification process.

20. Describe why carbonaceous material is needed in the denitrification process.

21. Describe three operational techniques for improving the performance of an Oxidation Ditch plant.

OXIDATION DITCHES

Glossary

Anoxic zone - area of relative oxygen scarcity, not necessarily completely anaerobic.

Brush aerators - a "river boat paddle-like" aerator.

Carbonaceous oxidation - biochemical oxidation of carbon containing compounds.

Carrousel - a variation of oxidation ditch design in which several circular tanks are built one-inside-the-other.

Disc aerators - large, vaned discs on a horizontal shaft.

Nitrogen oxidation - conversion of ammonia to nitrite and nitrite to nitrate.

Nitrogen reduction - conversion of nitrate to nitrogen gas.

Race track - the oval or loop shaped aeration basin in the oxidation ditch process.

Segmented wasting - the practice of wasting activated sludge solids periodically as opposed to large, one-time surges.

OXIDATION DITCHES

Lesson I - Introduction, Theory & Components

FOREWORD

In a way the word "pollution" is a bit of a misnomer. Whenever someone mentions pollution there is a tendency to conjure up visions of smelly debris ridden shorelines, industrial discharge lines gushing forth multicolored toxicants and signs warning of health risks in the old swimming hole. While at times man's incursion into the ecosphere has been extremely damaging, it is incorrect to believe that only negative results stem from the introduction of our waste into the environment. By recognizing the ability of the hydrosphere to absorb and treat waste within prescribed limits, it is entirely justifiable to deal with waste treatment from a cost benefit standpoint without jeopardizing adequate environmental protection. The role of waste treatment has therefore become one of managing man's contribution of waste to the environment.

HISTORY OF THE OXIDATION DITCH PROCESS

One method of providing this cost effective management stems from the use of activated sludge in what has come to be known as the Pasveer Oxidation Ditch Process, Loop Aeration, Carrousel Process, Orbital System, etc. The Oxidation Ditch concept was first developed at the Reserach Institute for Public Health Engineering (TNO), located in

the Netherlands, by Dr. Ir. A. Pasveer. Its purpose was to provide a low cost easy to operate method of handling small municipal and industrial waste treatment requirements. Placed into service in 1954 at Voorshoten, Holland,[1] the process served a population equivalent of 369 persons. However, because of the relatively inexpensive construction and maintenance costs and the ability of the process to deliver high quality, stable operations with a minimum of operational vigilance, the Oxidation Ditch approach has become increasingly popular worldwide. As of 1975 the EPA estimated that there were 558 Oxidation Ditch plants operating in the U.S. with a steadily increasing number coming on line each year.

VARIOUS DESIGNS OF THE OXIDATION DITCH

Essentially, the Oxidation Ditch is an application of the extended aeration, complete mix concept of activated sludge. Utilizing a closed loop trench or race track aeration tank configuration, the Oxidation Ditch represents a substantial design departure from conventional activated sludge systems. In many smaller Oxidation Ditch plants the aeration tank is simply excavated out of the ground. By sloping the banks of the ditch and lining the interior with an impermeable substance (usually clay or asphalt) a large cost savings can be realized in construction. Such a simplistic approach to waste treatment is very attractive to low volume users.

Since the inception of the process, the cost advantages which the Oxidation Ditch process enjoys have resulted in the development of plant capacities much greater than those envisioned in the original design. However, when the system is simply expanded to meet the needs of larger municipal and industrial users, such problems as aeration effectiveness, detention times, hydraulic flow patterns, etc., erode much of the process advantages. To overcome these challenges the Oxidation Ditch process has evolved in several different ways.

MULTI-TRENCH SYSTEMS

One method of avoiding the previously mentioned pitfalls has been through the use of multiple trench systems. Essentially, this design approach is a multiplication of the more manageable size units used in smaller treatment flows. While replication of the basic design offers a logical alternative for expanded capacities, the actual application of the principle tends to fall victim to negative factors which are not significant in single units. Potential burdens, such as large construction sites, increased capital outlays for construction and materials, magnified operational and maintenance costs, etc., can quickly reduce the cost benefits of the process when compared to other systems.

CARROUSEL SYSTEMS

In order to avoid some of these negative spin-offs in larger applications, a system known as a Carrousel has recently evolved. Utilizing the basic principles developed by Dr. Pasveer, the Netherlands based consulting firm of Dwars, Heederik, and Verhey developed the Carrousel process in the mid-sixties. The advantages of the Carrousel revolve around the areas of construction, aeration, and hydraulic principles. Essentially, the system consists of several free standing prestressed concrete tanks set one inside the other. Approximately 15 feet in depth, the secondary clarifier occupies the innermost tank with the aeration tank surrounding it. Within the aeration tank, a dividing partition is erected which serves to separate the tank into two channels. By terminating the partitions near each aerator the Mixed Liquors can be channeled so that the necessary hydraulic velocities (approximately 1 FPS) can be generated with minimum energy requirements. In approaching the construction of the Carrousel in this way both the aeration and clarification function of activated sludge can be accomplished within a single unit. This unique space utilization saves on land acquisition needs, construction and materials requirements, operational and maintenance demands, etc., all of which lowers the overall costs of the unit and increases its attractiveness in the 5-20mgd application range.

ADVANTAGES AND DISADVANTAGES OF THE OXIDATION DITCH

In general the Oxidation Ditch process, whether basic or complex, have certain factors in common with each other. To begin with, all oxidation ditch systems use a form of activated sludge, using some form of secondary clarification to remove coliodial and dissolved solids. By allowing micro-organisms to incorporate organic material into their cell bodies, waste material which would otherwise be lost to the environment is retained in the treatment system. Next, all Oxidation Ditch plants run in what is known as the extended aeration mode. Utilizing fluid detention times of between 12-24 hours, these systems are designed to retain solids in the neighborhood of 15-30 days. Such long solids retention times promote endogenous respiration of the cell mass. In essence what an Oxidation Ditch plant is designed to do is starve the microorganism through the course of the treatment process and thereby reduce the amount of solid waste which must ultimately be handled. By converting waste material into carbon dioxide, water and energy, microbes can in conditions of severe endogenous respiration reduce solids handling by 50% or more over conventional approaches. Some extra expense is initially required for the construction of larger systems needed in an extended aeration plant. However, the EPA estimates that the Oxidation Ditch process is the cheapest systems to build and operate within the

0.1 to 4.0 mgd flow range (1). With the advent of the Carrousel design, competitive bids of nearly any flow range are now possible. Presently, Oxidation Ditch plants of 15 mgd are on line in the U.S. with even larger units under development.

Another advantage of the Oxidation Ditch process stems from the nominal operational requirements which the system has. High MLSS levels and long detention times enable the process to recover from shock loadings and adverse conditions with only minimal operational supervision. From a comparison standpoint the oxidation process requires perhaps the least amount of operational guidance of any activated sludge design. Such stability becomes an important asset to communities and businesses where only intermittent attention can be paid to the system.

The Oxidation Ditch process also encompasses the ability to nitrify and denitrify within the same physical structure (refer to nitrification/denitrification section). More conventional systems require the construction of separate facilities and the introduction of costly external carbon sources (usually alcohol) in the elimination of nitrogen from waste water. With the oxidation system, the design of the plant incorporates the ability to maintain conditions which will remove nitrogen without special equipment or chemicals. However, there are inherent limits on the efficiency of this

form of nitrification/denitrification which must be traded off when comparing the system's desirability with other nitrogen removal techniques.

AERATION OF THE OXIDATION DITCH

The basic philosophy of aeration is to develop dissolved oxygen levels in the mixed liquor and keep the flock particles in activated sludge from settling out in the aeration tank. The trick in aeration is to stimulate the absorption of oxygen gas from the atmosphere by breaking through the surface tension of the MLSS. Surface tension is the property of a surface that imparts a membrane-like behavior to that surface. It is this membrane-like behavior which forms a resistant barrier to the free transfer of atmospheric oxygen into solution with the mixed liquor. In the Oxidation Ditch process mechanical aeration units of various designs are used to disrupt the surface tension of water and develop necessary dissolved oxygen levels for the system.

A mechanical aeration unit is nothing more than a device which beats the surface of the mixed liquor creating a splash zone where atmospheric oxygen is entrapped and absorbed into solution with the water. The dissolved oxygen and hydraulic flows generated through the use of these mechanical aerators have special significance to the Oxidation Ditch plant for several reasons.

The first area of importance in aerating activated sludge centers around the requirement for dissolved oxygen

by the microbial populations. It is necessary to provide sufficient dissolved oxygen to a bio-mass in order to promote efficient oxidation of waste material. Essentially, microbes consume waste and convert it through a process known as "biological oxidation", into water, carbon dioxide, energy and more microorganisms. Everyone has watched wood burn in a fireplace. This is the same thing which aerobic micro-organisms accomplish on a smaller scale. Simply stated, the organism of activated sludge burns up waste material in sewage when provided with sufficient oxygen. In the case of carbonaceous material (organic carbon) approximately 1.25 mgs of oxygen are required to oxidize one mg of carbon. By itself this requirement places a substantial burden on the aerators to provide adequate D.O. to the system. However, the Oxidation Ditch was also designed to oxidize ammonia-nitrogen compounds to nitrate. This process, referred to as Nitrification, has a requirement for 4.57 mgs of oxygen for every 1 mg of Nitrogen converted to Nitrate. It is easy to see how even relatively low concentrations of Nitrogen can place a severe demand on the dissolved oxygen generating capabilities of the aeration equipment in the Oxidation Ditch plant. Figures on the effective oxygen requirements of a combined carbon/nitrogen oxidation system range from 1 to 3 ppm O_2. The important thing to remember when developing adequate dissolved oxygen levels for a plant are that these requirements are

not static through the course of a day. Dissolved oxygen needed in the Oxidation Ditch system is a dynamic process linked to factors such as microbial growth rates, diurnal flow variations, the strength and quality of the influent sewage, temperature, etc. It is the job of operations to routinely monitor the oxygen requirements of the system and act as a regulator between stability in the process, and the costs of oxygen generation. As a result, the minimum D.O. levels of a plant is situationally dependent.

The second important area of concern with aeration in the Oxidation Ditch process involves the physical agitation of the mixed liquor by mechanical aerators. Normally speaking, the dominant way in which activated sludge is held in suspension is through the use of randomly directed turbulence. Dr. Pasveer designed the Oxidation Ditch aeration tank in the shape of a race track. In this way, turbulences are directed around the tank and transformed into directional velocities. As a consequence, the Oxidation Ditch process uses fluid velocities and not turbulence as the primary method of particle suspension. There are several advantages to this movement which conventional aeration doesn't enjoy. To begin with, the creation of directional fluid in the aeration tank substantially reduces the possibility of dead zones. A dead zone is a pocket of activated sludge which does not receive adequate mixing and becomes stagnant. In the Oxidation Ditch

process fluid velocities of one foot per second effectively eliminates any chance of inadequate mixing. Also there are no square corners in the design of the aeration tank where solids can accumulate and cause problems. Because the movement of MLSS in an Oxidation Ditch plant is directional, it is possible to space the aeration units in a way which will create regions of relative oxygen scarcity or anoxic zones. The anoxic zone is absolutely essential to the denitrification process (refer to the denitrification section) and allow the system to remove nitrogen from waste water. Finally, the directional movement of MLSS in the Oxidation Ditch has the advantage of promoting good flocuation and contact between waste material and micro-organisms. Since the process does not require severe agitation of the mixed liquor in order to satisfy its oxygen demands. The formation of high quality flock particles are allowed to proceed relatively undisturbed. This creates an environment where both the size of the flock particle and the time it has to contact the waste are increased, thus enhancing effective treatment.

TYPES OF AERATION USED IN THE OXIDATION DITCH PROCESS

In order to achieve the dissolved oxygen needed in the Oxidation process, several different types of mechanical aeration devices are used. Many small systems make use of what is known as "Brush Areation". Cylindrical in shape, these aerators straddle the activated sludge channel, creating

the necessary dissolved oxygen and fluid velocities by rotating quickly through the surface of the mixed liquor. A good analogy of the brush aerator would be the action of an old time river boat paddle wheel as it pushed against the water. By far the brush aeration unit is the most common method of providing oxygen to an Oxidation Ditch system, however, there are still a number of detractions connected with their use. Relatively high rotational speeds (approximately 78 RPM), restrictions on the effective length of the brush, bearing placements and alignment difficulties, high costs to oxygen generation ratios, etc., tend to make the brush aerators unsuitable for larger applications.

To overcome these difficulties, horizontally mounted disc impeller aeration units are coming into greater favor. By partially submerging a vaned, conically shaped impeller in the aeration channel, the efficiency of dissolved oxygen generation and fluid velocities is improved. Slower rotational speeds (23-32 RPM), durability, large impeller sizes (some exceeding 3 meters), high oxygen transfer efficiencies, etc., all translate into making the horizontally mounted aerator useful in large scale applications where other forms of aeration are not practical. Oxidation Ditch plants in excess of 15 mgd capacities clearly show a shifting of emphasis toward the needs of larger users. The development of impeller aeration has played a significant role in enabling

competitive bids to be made on such mid-range capacity plants and will continue to enhance the desirability of the system.

SAFETY COVERS FOR AERATOR UNITS

As a final note on aeration, something needs to be said about the usefulness of shielding on aerators. Not only are the questions of safety and aesthetics of importance when considering shielding. In the colder climates, ice on the aeration tank produce significant problems with the maintenance of the equipment. The judicious use of baffled sheet metal and bar screening can be used to enclose and protect both the aeration equipment and surrounding area. Risks associated with injury and contamination from MLSS backspray, coupled with the potential threat of icing in some regions, makes enclosure of aerators not only a good idea but a profitable one as well.

CLARIFICATION

Another concern with the design of the Oxidation Ditch process is the clarification of the activated sludge. Once the microorganisms have consumed the waste organics present in sewage, it is necessary to allow the mixed liquor which composes activated sludge, to settle in a hydraulically quiescent area. In this environment solid material will separate from the waste water and clear liquid can be supernated off for final chlorination. The process of separating activated sludge

from final effluent is known as a "Secondary Clarification" and is fundamental to the overall efficiency of an Oxidation Ditch plant.

PHILOSOPHY OF CLARIFICATION

The basic philosophy of clarification revolves around the establishement of a quiet, slow-moving area where activated sludge can be decanted. Microorganisms which inhabit a treatment plant are nearly entirely composed of water. As a consequence, the specific gravity of the solid material which must be settled out is almost identical to that of water. Specific gravity is determined by comparing a volume of sludge with an equal volume of distilled water.

$$\text{sp. gr.} = \frac{\text{weight of sample}}{\text{weight of distilled water}}$$

From a settling standpoint this is critical. Substances with a specific gravity of greater than one will sink, and those with values less than one will float. In order to achieve specific gravities in activated sludge great enough to sink, it is necessary to encourage the formation of floc particles. Floc is an agglomeration of waste held together by a sticky substance which microorganisms coat their outer cell wall. The mechanics of floc formation is fairly complex and beyond the bounds of this module. However, it is important in the operation of a clarifier that a certain minimum quality of floc be generated in order to promote settling.

CHARACTERISTICS OF SLUDGE SETTLING

One excellent way of determining the sludge settling characteristics of your floc is to perform a settlometer test on the MLSS. The test consists of nothing more complicated than a couple liter clear plastic container, markings every one hundred milliters and some MLSS. To run a settlometer test, grab a representative MLSS sample, place it in your marked container and watch it for one hour. The objective of the test is to provide a graph of the settling rate of the sludge in five minute intervals for the first half hour. In a process which has the correct sludge conditions you will expect to see a graph which falls off by 40-50% the first ten minutes and then gently tapers off to between 65-75% of its original volume. Where the sludge is too young, your graph tends to stay straight and falls slowly. In plants with too old a sludge, the graph plummets and then tapers off to a straight line.

Another way to manipulate date gained by graphing sludge settling characteristics is through the calculation of the Sludge Volume Index (SVI). The SVI is defined as the volume of sludge occupied by one gram of sludge. It is calculated by multiplying the milliliters of settled sludge after 30 minutes by 1000 and then dividing that figure by the mg/l of MLSS.

$$SVI = \frac{\text{ml of Settled Sludge (30 min.) X 1000}}{\text{mg/l OF MLSS}}$$

In a well running Oxidation Ditch the SVI remains generally in the neighborhood of 100, A SVI ranging between 75-100 is not uncommon, whereas high figures of 150-200 or low fighres of 0-50 indicate a plant upset condition. A good control technique is to plot the SVI against the quality of the effluent until an optimum plant operating range is established.

MECHANICAL ASPECTS OF CLARIFICATION

Secondary clarification in the oxidation ditch process is composed of the same basic equipment which makes up clarifiers in any of the more conventional activated sludge plants. The main components include squeegy bladed rake arms and draft tubes, a drive assembly to turn the rake arms, a center hopper for the waste removal, a center feed well for the activated sludge to enter from the aeration zone, etc. Some smaller systems are unique in that they attempt to accomplish clarification within the aeration tank itself. By shutting down the aerators for a period of time the aeration channels can be turned into a clarifier for the MLSS. Such an approach has certain cost advantages, however, the lack of wasting control and the inability to aerate solids while under clarification shows up in a reduced solids removal efficiency. Many of these dual function systems are promoted as never requiring wasting. This is patently not true. Ultimately the system must become self wasting and aeration solids will flow out with the effluent. It is necessary in the process

control of the Oxidation Ditch to both periodically remove old microorganisms from the system (waste) and establish an environment which returns useful settled sludge back to an aerobic environment before serious oxygen deprivation can occur. Separate stage clarification is much more adapted to providing these needed conditions than combined systems and consequently, play a greater role in the designs of the system.

THE ROLE OF SLUDGE SETTLING IN CLARIFICATION

Characteristically activated sludge has a tendency to stratify in the course of settling. This is important in the clarification step of the Oxidation Ditch effluent. As a rule of thumb, one expects to find older microorganisms settling quickest with successively younger organisms predominating later deposits. Secondary clarification takes advantage of this stratification in the wasting and returning of sludges. By sloping the floors of the clarifier, the older, less active sludges tend to migrate toward the center of the tank where they are removed as waste. Correspondingly, the younger, more active microbes tend to gather around the edges of the tank where they can be sucked up by draft tubes and returned for continued service in the aeration tank. Both the process of wasting and returning of solids in the clarifier are vital to the overall performance of the system. Failure to manage a proper solids inventory can only lead to a reduced quality of effluent.

SOLIDS INVENTORY CONTROLS

An important consideration in the management of solids in the secondary clarification is the survey and control of the Sludge Blanket Depth (DOB). Unless the D.O.B. is maintained at approximately one quarter of the clarifier sidewall depth, one runs the risk of losing solids in periods of high hydraulic loading. Perhaps the easiest way to monitor the D.O.B. is through the use of a Sludge Judge. Nothing more than a clear plastic pipe with a one-way valve at the bottom, the Sludge Judge can be used to easily obtain core samples of your clarifier. Routine examination of such core samples will enable an operator to very accurately determine whether or not the level of the blanket is shifting. For instance, a rise in the D.O.B. is noted; by turning up the R.A.S. return rate this increase can easily be counterbalanced. Generally speaking the Oxidation Ditch process operates well with a R.A.S. rate of 40-45% of the influent flow rate. However, it is important when adjusting the return rate to bear in mind the hydraulic pressures which are being artificially created. By making any changes in small increments of no more than 5%, the chances of negative side effects can be reduced.

Wasting out of the secondary clarifier is perhaps the most useful process control which you have in an Oxidation Ditch plant. Although the Oxidation Ditch process runs in the

extended aeration mode, thus dramatically reducing the solids generation of the system, it is still necessary to waste periodically in order to remove solids which are resistant to endogenous respiration. The Food to Microorganism ratio (F/M ratio), Sludge Volume Index (SVI), Mean Cell Residence Time (MCRT) or Solids Retention Time (SRT), etc., are all dependent on wasting in their control and adjustment. Perhaps the easiest and most consistent way of arriving at a poundage figure for wasting is through the use of SRT values. This Solids Retention Time is defined as the total pounds of solids in the secondary system divided by the number of pounds of solids wasted or lost in the effluent.

$$SRT = \frac{\text{Pounds of Suspended Solids in the Total Secondary System}}{\text{Suspended Solids Wasted, lbs/day + Suspended Solids lost to the Effluent lbs/day}}$$

In other words, this calculation is a rational description of sludge age which takes into account the entire secondary system. Ordinarily, the Oxidation Ditch process runs best with a SRT of between 15 and 24 days. Once the optimum retention time is established for the plant, the simple manipulation of the equation will provide each day's wasting requirement. For a more complete description of SRT refer to the Standard Methods for Water and Waste water. Whatever technique is chosen, it is important to pick one which correlated well with effluent quality and is easy to routinely apply to the question of solids removal.

THE IMPORTANCE OF SEGMENTED WASTING SCHEDULES

Once a daily wasting figure has been arrived at, it is best to break the withdrawal up into a segmented schedule. Withdrawal of the waste several times over the course of a day avoids the pitfalls associated with removing waste all at one time. For instance, wasting for only short periods of time, with an interim period for solids build up, will significantly increase the solids concentration of the waste and reduce the equipment wear, energy requirement and burden on down stream sludge handling facilities which the transfer of excess water brings. Also it is important to remember that the objective of wasting is to remove the old and dead bugs while allowing the young active microbes to return to the process for further treatment. The en masse wasting of the daily poundage requirement creates a condition of diminishing returns, whereby after a certain point the useful microorganisms are removed along with the less desirable ones. In conditions of heavy organic or toxic shock loading, the destabilizing effects of removing extensive quantities of sludge over a short period of time can leave the system with an insufficient bio-mass to effectively treat incoming waste. Breaking up the wasting into a segmented schedule allows time for the microbial population to stabilize itself, resulting in a smoother growth curve and more consistent operations.

PROCESS HINTS FOR THE OXIDATION DITCH PLANT

One of the most important parts of an Oxidation Ditch process is the preventative maintenance program of the plant. The "guess and by golly" approach to maintenance will always end up costing more in time, materials and reduced plant efficiency than a well thought out program of preventative maintenance. First, establish a systematized card file which locates and describes the maintenance requirements of each piece of equipment in the plant. Second, prioritize the equipment according to the manufacturer's recommended maintenance schedule, importance to the plant, availability of repair materials, etc. Some equipment simply can not be allowed to fail, otherwise the plant is out of business. By including a description of the pieces of equipment, the order numbers, the best place to order parts from, etc., valuable time can be saved in emergency situations. Third, establish a card filing system which can be readily sorted. In small plants rummaging through a stack of cards may be acceptable. However, when the cards start running into the hundreds this approach will not work due to equipment which might be ignored. The judicious use of holes punched according to a time sequence, equipment priority, parts number, etc., can expedite the speedy recovery of needed information with a minimum of time and confusion. Presently, there are several card file systems on the market which can be purchased in lieu of a "do it yourself" catalog.

With regard to the maintenance of Brush Aeration units, a number of problems have cropped up with the placement bearings and the alignment of the brushes. It is exceedingly hard to keep these types of aerators in true alignment for extended periods of time. Once a misalignment occurs torque and the high rotational speeds of this type of aerator will quickly wear out bearings. A yearly alignment adjustment will minimize the problems associated with sagging and will reduce the need for unscheduled maintenance. It is important to remember that while routine maintenance may not be exactly fun, it is certainly better than constantly fixing equipment which has broken down for lack of it.

Directly related to the performance of the aeration unit is its ability to generate fluid velocities needed to suspend the mixed liquor solids. One way to check on this movement is to place a stick in the flow and time its progress. The float should be weighted so as to penetrate approximately two thirds of the way to the bottom of the channel. By timing the float's progress in a number of different locations, an idea of the average channel velocity can be determined. A generally accepted minimum for fluid velocities in the Oxidation Ditch process is one foot per second.

In conclusion, there is the routine of sampling and testing. The methods by which information is gathered about the plant processes is completely dependent on the quality of the sampling technique. The urge to get out of the cold, wind, or night air, etc., has led more than one operator to discover easy ways to generate data. Holding one's finger in the air, consulting metaphysical tables and penciling in data are not useful ways to collect pertinent data and samples. It is very important to take samples which reflect an average part of the whole. Avoid taking samples in only a portion of a tank. Try to gather samples from various depths. Most of all, decide what types of samples you need before you gather them. Always utilize Standard Methods in preservation of samples and you will ultimately find a great reduction in problems associated with poor sampling techniques.

It is important to remember the computer slogan: "garbage in -- garbage out."

OXIDATION DITCHES

Lesson II - Process Kinetics & Process Control

FOREWORD

In this section of the Oxidation Ditch module we will be describing the major process kinetics of the system and looking at the concerns which must be addressed when treating waste. Essentially, the oxidation ditch process is designed to perform three major functions. First, as an activated sludge system, the process has the capability to oxidize carbonaceous material. Second, due to the design and operations of the process, nitrification of ammonia-nitrogen compounds can be accomplished without the need for special systems and chemical additions. Third, the process can remove nitrogen entirely from the wastewater by converting nitrates (oxidized ammonia-nitrogen compounds) into nitrogen gas which then passes out of solution and is lost to the atmosphere. These three main groupings can, in turn, be lumped into the broad categories of oxidation and reduction. In the following material we will examine each group from the standpoint of what composes it, how it affects the treatment process and environment, how it is controlled from a process standpoint, and finally what an operator might do in order to help the plant run smoother.

CARBON IN THE ENVIRONMENT

Carbon is an absolutely necessary component of life. By definition all organic molecules must contain some degree of carbon. As such, carbon has become a common heritage for all life. Through a process known as "Carbonaceous Oxidation," microorganisms break down organic carbon molecules into a food source. They then in turn, become food for other organisms, thus building a food chain. This food chain is completed when higher life forms, eliminate waste containing organic carbon which the microorganisms once again use for food. Simply stated, organic carbon or carbonaceous material supports the primary fuel supply of life on this planet. Man and his activities liberate vast quantities of usable carbon into the environment. In doing so we have become responsible for degrad-in the quality of the environment by providing too much of a good thing. We have in essence over-stimulated a natural balance to the point where it becomes self-destroying.

CARBONACEOUS OXIDATION

One of the main concerns of wastewater treatment is the removal of organic carbon compounds found in sewage influent. In the case of the Oxidation Ditch process, dense populations of microorganisms accomplish this removal by utilizing organic carbon and oxygen as a source of energy. This process is known as biological oxidation or aerobic respiration. By artificially maintaining concentrations of microbes, essentially all soluable organic carbon found in wastewater can

be converted to H_2O, CO_2, energy and more microorganisms. This conversion is exactly the same mechanism which nature uses in the removal of waste material from the environment. Essentially, by compressing and controlling concentrations of microbes, man has domesticated these naturally occurring processes into a system which can be used to manage his contributions of waste into the ecological system.

PROCESS CONTROL OF CARBONACEOUS OXIDATION IN A OXIDATION DITCH TREATMENT PLANT

The way in which carbon supports a food chain carries over into the microbial populations that clarify raw sewage. Organic carbon found in wastewater provides the backbone for an increasingly complex hierarchy of microorganisms found in activated sludge. Further, as is the case with the Oxidation Ditch system, the denitrification process is directly supported by the presence of carbonaceous material (refer to the denitrification section). It is completely beyond the scope of this module to attempt to explain the chemistry of carbonaceous oxidation in sewage. Because of the myriad of different compounds found in wastewater it would be nearly impossible and certainly unprofitable to adequately describe the chemical kenetics of the Oxidation Ditch. From a process control standpoint one need only remember that organic carbon compounds are broken down by microorganisms in the

presence of oxygen, forming H_2O, CO_2, energy and more micro-organisms. A common organic carbon component of sewage is glucose or sugar. Under carbonaceous oxidation the glucose will break down according to the reaction formula:

$$C_6H_{12}O_6 \text{ (glucose)} + 6O_2 \xrightarrow{\text{microorganisms}} 6CO_2 + 6H_2O + 686 \text{ Kcals/mole} + \text{more microorganisms}$$

In the Oxidation Ditch process the capability exists to oxidize both organic carbon and nitrogen compounds. This dual function is the actual key to maintaining efficient process controls. Because nitrification (nitrogen oxidation) kinetics are relatively more sensitive than carbonaceous oxidation, as a matter of practice, operational guidelines are shifted in favor of promoting nitrification. By placing greater emphasis on nitrification in process control, the effective carbon removal rates are not significantly changed, while at the same time nitrogen oxidation within the system is substantially improved. As a consequence, process control of carbonaceous oxidation can be covered in the same section as nitrification. However, the recognition of carbon's role in sewage dynamics will enable operations to formulate a clearer understanding of the factors promoting effective treatment and as such should not be ignored.

NITROGEN AND SEWAGE TREATMENT

In this next section of the Oxidation Ditch module we will look at the effects of nitrogen, the kinetics of its removal and how to control the process for effective removal efficiencies.

At one point in the evolution of sewage treatment in this country, there was a major concern over the concentrations of NH_4^+ (ammonium ion) present in the effluent. In fact, the concentration of ammonium was used as the main standard for effluent discharge. With the advent of the BOD_5 test, the emphasis on control shifted away from nitrogen. Further, engineers found it more economical because of the lower O_2 requirements, to design new plants around the elimination of carbonaceous organic material and exclude the question of nitrogen compounds. In this sense, the development of effective nitrogen removal techniques are only now beginning to achieve the state of the art which was enjoyed in the early 1900's.

THE IMPORTANCE OF NITROGEN IN THE ENVIRONMENT

Nitrogen exhibits several properties which make it both an essential atom and one which can severly impact the environment and the treatment facilities. The atom itself has the ability to become tied into a great number of different chemical reactions. As a consequence, nitrogen, along with phosphorus, carbon, oxygen, and hydrogen has become one of the

major building blocks of life on Earth. However, nitrogen, like oxygen, can create environmental concerns when present in overabundance. Increasingly, it is becoming necessary for man to control his contribution of nitrogen in order to avoid the detrimental effects which it can have on lakes, streams, and oceans. The following is a discussion of where nitrogen comes from, some of the concerns with it and ways in which nitrogen removal can be accomplished through the use of the Oxidation Ditch process.

SOURCES OF NITROGEN

Most of the nitrogen which man introduces into the environment is the result of run-off from agricultural lands where nitrogen is used as a fertilizer. However, the nitrogen present in raw waste water is also a major contributor and it is the job of treatment plants to remove this source. Primarily, nitrogen in raw sewage results from the urine and feces which domestic sources produce. The estimated contribution of these two sources of ammonia-nitrogen range from 1-2 g/day/adult for feces, to 0.5-3 g/day/adult for urine (2). Because nitrogen is such a versatile atom it becomes tied up in nearly all the proteins and enzymes which are essential for life. This propensity of nitrogen to involve itself with the life processes carries over into the micro-organisms which make up activated sludge. The associated

nitrogen in a cell mass is approximately 0.07 lbs/lb BOD_5 at a zero SRT and 0.015 lbs/lb BOD_5 at an infinite SRT or about 9% of the cell mass as nitrogen (3). Both the external and internal sources are contributors of nitrogen and as such play a part in the kinetics of the treatment process.

CONCERNS WITH NITROGEN

Biostimulation is one of the major concerns in controlling nitrogen. Nitrogen, along with phosphorus, carbon dioxide and sunlight are fundamental in the growth of algae. In the presence of excess nitrogen, algae can grow unchecked into what are referred to as algae blooms. These blooms can spoil the aesthetics of the water, create odor problems in their decay and reduce the dissolved oxygen levels to concentrations lethal to aquatic life. Further, there is a tendency for lakes to store and recycle nitrogen compounds, thus, perpetuating recurring algae build-ups and enhancing the premature eutrophication of the water body.

Nitrogen can also exhibit direct toxic properties. Under certain conditions fish, when exposed to nitrogen in the form of ammonia (NH_3) may die. Normally speaking ammonia (NH_3) does not occur naturally, however, in an elevated pH environment the ammonium ion (NH_4^+) will transform to ammonia in accordance with the following formula.

$$NH_4^+ + OH^- \xrightarrow{\text{(elevated) pH}} NH_3 + H_2O$$

Because of the synergistic interaction which ammonia has with dissolved oxygen levels, carbon dioxide, temperature and pH it is difficult to make definitive conclusions about effective levels of toxicity. Some research into the question has indicated that ammonia as low as 0.01 mg/l will produce debilitating effects on fish populations (4).

Directly relevant to the operation of a sewage treatment plant is the effects which ammonia-nitrogen compounds have on the efficiency of the disinfection process. The ammonium ion (NH_4^+) will directly react with hypochlorous acid (HOCl) and produce what are called chloramines. The following chemical expressions are for the generation of chloramine compounds:

$$Cl_2 + H_2O \longrightarrow HOCl + H^+ + Cl^-$$

$$NH_4^+ + HOCl \longrightarrow NH_2Cl \text{ (monochloramine)} + H_2O + H^+$$

$$NH_2Cl + HOCl \longrightarrow NHCl_2 \text{(dichloramine)} + H_2O$$

$$NHCl_2 + HOCl \xrightarrow[\text{(elevated) pH}]{} NCl_3 \text{ (nitrogen trichloride)} + H_2O$$

The problem with chloramines stem from the fact that these compounds are much less effective oxidizer than the original hypochlorous acid. As a result, much larger quantities of expensive chlorine must be used to achieve a given level of disinfection. Beyond the expense, chloramines are not

desirable in wastewater due to their relatively long life spans. In conditions of low flow and elevated temperatures, effluent containing concentrations of chloronitrogen compounds can significantly degrade the water quality in the receiving stream.

Another area of concern with nitrogen compounds is their impact on the pH of the treatment plant and receiving waters. Although this process of alkalinity destruction will be covered in much greater detail later, be aware that the process where certain types of microorganisms oxidize nitrogen can create serious drops in pH values. 7mg of alkalinity, measured as Calcium Carbonate ($CaCO_3$), are required to oxidize lmg of ammonia-nitrogen. This destruction of alkalinity can seriously depress the pH of an aquatic environment should it be carried too far.

Perhaps the greatest concern with ammonia-nitrogen is the dissolved oxygen demand which it places on both the treatment facility and receiving water ecology. Approximately 4.75 mg. of oxygen are required to oxidize lmg. of ammonium (NH_4^+-N) to nitrate. This is compared to approximately 1.25mg. of oxygen which carbonaceous material require in their process of oxidation. It is easy to see how even relatively small quantities of nitrogen can place a significant oxygen requirement on a system. The Oxidation Ditch process, because of its long detention time and physical design is ideally suited for the elimination of nitrogen. In the following discussion we will be looking specifically at how the process accomplishes this task.

NITRIFICATION/DENITRIFICATION

Simply stated, biological nitrification/denitrification is where certain types of aerobic microorganisms first oxidize ammonium ions (NH_4^+) to nitrate (NO_3^-). Next populations of facultative microbes reverse the process and reduce the nitate to free nitrogen gas (N_2) by stripping away available oxygen atoms. Partial pressure differences between the wastewater and atmosphere, then drive the nitrogen gas out of solution and nitrogen is lost from the system.

NITRIFICATION

In the first step, a process called nitrification, oxygen is attached to a nitrogen atom in two general steps. Initially, a group of microorganisms known as Nitrosomonas, oxidize ammonium ions to form nitrite (NO_2^-). This reaction takes place according to a general reaction formula of:

$$2NH_3^- + 0.3\ O_2 \xrightarrow{\text{(Nitrosomonas)}} 2\ NO_2^- + 2H_2O + 2H + \text{energy}$$

Following this step, a group of microorganisms known as Nitrobacter, complete the oxidation of nitrite to nitrate with the addition of an extra oxygen atom. This oxidizing step is accomplished according to the reaction formula of:

$$2NO_2 + O_2 \xrightarrow{\text{(Nitrobacter)}} 2NO_3^- + \text{energy}$$

DENITRIFICATION

As a second step of the conversion of ammonium to nitrogen gas, the now oxidized nitrate (NO_3^-) is, in turn, reduced by a wide group of microorganisms under the general type heading of facultative heterotrophs. These denitrifying microbes fall into a number of different strains including: Psuedomonas, Micrococcus, Achromobacters, Bacillus, etc. As a general process description, the dentrifying microorganisms reduce nitrate according to the following reaction formula:

$$NO_3^- + 0.33 \overset{\text{(sewage)}}{CH_3OH} \dashrightarrow NO_2^- + 0.67\ H_2O$$

$$NO_2^- + 0.5 \overset{\text{(sewage)}}{CH_3OH} \dashrightarrow 0.5N_2 + 0.5CO_2 + 0.5H_2O + OH^-$$

Overall Reaction

$$NO_3^- + 0.833 \overset{\text{(sewage)}}{CH_3OH} \dashrightarrow 0.5N_2 + 0.833\ CO_2 + 1.16\ H_2O + OH^-$$

One must realize that in both the nitrification/denitrification reactions that all is not the smooth and orderly procession that paper presents. There are a myriad of complex interactions which defies a detailed kinetic description of the system dynamics. This confusion is only enhanced when sewage is utilized as a substrata rather than of specific carbon source. However, there are ways to r . an Oxidation Ditch process which ignore much of this complexity and still produce good quality effluent. Hopefully, you will find information in the next section which will help you to control and upgrade

the treatment process in your facility.

PROCESS CONTROL OF AN OXIDATION DITCH PROCESS

Some of the control peculiarities which an Oxidation Ditch process exhibit stem from the need to essentially satisfy three different reactions; carbonaceous oxidation, nitrogen oxidation, and nitrogen reduction. The activated sludge process and specifically the oxidation ditch system, can satisfy the requirements of all of these varying reactions. To do this, however, certain environmental conditions must be maintained. For the sake of clarity we will approach process control from two directions. First, by lumping both the carbon and nitrogen into the category of general oxidation we can more easily see how the two reactions are interrelated. Second, the unique process control requirements of nitrogen reduction must be married to the total system dynamics. In other words, from an operational standpoint the Oxidation Ditch process requires you to balance the needs of two opposing functions, oxidation and reduction within the framework of a single system. Unless this balance point is carefully chosen, you will find it difficult to obtain maximum efficiency out of the system. In the following discussion we will examine how effective controls and measures can be placed on these three separate and distinct reactions while maintaining integrity on the system as a whole.

PROCESS CONTROL OF CARBONACEOUS AND NITROGEN OXIDATION

In the control of the oxidation reactions in your plant, there are a number of ways to approach the subject. Trite as it might sound, one of the most helpful things which you can do for the system is nothing. By schooling yourself in the "wait and see" philosophy, many of the plants short-term breaks in efficiency become self-correcting. This is particularly true of the Oxidation Ditch process, once certain gross parameters are met, the system tends to be self-regulating. The operator who, upon seeing a change, immediately initiates some counter-balancing control step, may in effect be "cutting his own throat." In a very real sense sewage treatment requires a delicate touch. You must first be certain any changes being observed are long-term and/or serious in nature; and next you must introduce only those changes in the process which do not cause more damage than they cure. In other words, you do not have to fix it if it is working. One way to avoid the pitfalls of negative reinforcement is by utilizing a five-day moving average on your control parameters. This enables you to adjust to changing conditions in a slow, easy manner and avoid much of the helter skelter conditions which quick reaction times, but limited knowledge can bring.

However, all of these cautionary notes do not address the topic of what control techniques and gross parameters are needed to run an Oxidation Ditch.

Perhaps the most significant item which is useful in setting up a viable environment for biological oxidation is an understanding of the microbes involved. It becomes apparant when studying the requirements of the different organisms responsible for carbon and nitrogen oxidation that the nitrogen group, known as nitrifiers, are relatively delicate bugs. Although the basic requirements of D.O., specific pH levels, temperature, access to a food source, etc., are fundamentally similar. The factors which dictate efficiency in nitrification run in a much narrower band than do those governing the activities of the carbonaceous group. As a consequence, you will be able to control your plant in favor of nitrifiers without hampering the efficiency of carbonaceous oxidation. In the following discussion we will approach the question of controlling the oxidation process from the standpoint of promoting the most favorable conditions for nitrification and allowing carbonaceous oxidation to follow as a matter of course.

The first major requirement in controlling the oxidation process is the establishment of adequate dissolved oxygen for the microorganisms to thrive. It is important to recognize just how aerobically inclined Nitrobacteraceaes (Nitrosomonas and Nitrobacters) really are. Approximately 4.57 mgs of oxygen are required to oxidize 1mg of ammonium-nitrogen to a nitrate compound (NO_3^-). This is compared with 1.25mg of D.O. needed for the oxidation of 1mg of carbonaceous material. It

is easy to see how even relatively low concentrations of nitrogen can cause substantial demands on the system's ability to provide adequate free oxygen. In order to meet the dual goals of carbon and nitrogen removal, it is necessary to maintain excess dissolved oxygen levels of at least 1ppm. Some authorities advocate residuals in the neighborhood of 3ppm. These greater residual increase safety margins, but tend to be more costly and really do not add to the overall effectiveness of the process. Recognize, however, that by maintaining relatively low D.O. levels it will be necessary to closely monitor the aeration zones. Diurnal flows can cause fluctuations in the oxygen requirements of the microorganisms metabolic processes. By routinely regulating the aeration zone for changes, the operators can reflect system changes and create a proper microbial environment while containing costs.

One peculiarity which develops in the maintenance of nitrifying microorganisms in the Oxidation Ditch process, stems from these microbes relatively long reproduction time. Normally speaking, microorganisms found in wastewater double their population every 30 minutes. In the case of Nitrobacteraceae (Nitrosomonas and Nitrobacter), their doubling time runs in the neighborhood of 30 hours. From an operational standpoint, what this translates into is a tendency to over-waste the nitrifying organisms while attempting to control the general population of bugs. Experience with other plants indicates

SRT (solids retention time) of 7 days will minimize the impact of the wasting program. However, because of the design considerations of the oxidation ditch, SRT's from 15 to 30 days are common. These long retention times are one of the major advantages of the system when controlling for nitrification. A positive consequence of controlling wasting in favor of nitrogen oxidation is a tendency toward higher MLSS concentrations. MLSS concentrations of 4000-6000mg/l are not uncommon in the Oxidation Ditch process. Such high solids loading rates provide not only the long SRT's required by the nitrifiers, but also buffer the system against shock loading and toxicants as well.

Concentrated BOD or toxic shock loads can both be more effectively handled in a system which has excess populations of microorganisms. By running a high MLSS in the Oxidation Ditch process you end up creating a buffer of microorganisms which resist changes in the quality of the effluent.

Another area of concern when attempting to establish and maintain a population of nitrifying organisms is the toxic effect which certain heavy metals can have. Such substances as zinc, copper, nickel, chrome and especially silver, can seriously inhibit nitrification. In guarding against toxicity, it is important to know what types of industries discharge into your plant. Higher levels of contamination can be tolerated if the concentrations of toxicants are metered out at a constant value. By developing cooperation from the industrial sector,

problems associated with concentrations, shock loadings, types of material, etc., of toxic waste can be dealt with much more successfully.

In the process of nitrification, pH values can be depressed through the destruction of carbon dioxide and ammonia. During the oxidation of ammonium approximately 7mgs. of alkalinity (measured as $CaCO_3$) are destroyed, per 1mg. of ammonia-nitrogen oxidized to nitrate. This reduction of alkalinity can be described according to the following reaction formulas:

Oxidation Nitrosomonas	$NH_4^+ + 0.5O_2 + 2HCO_3^- \dashrightarrow NO_2^- + 2H_2CO_3 + H_2O$
Oxidation Nitrobacters	$NO_2^- + 0.5O\ _2 \dashrightarrow NO_3^-$
Oxidation Overall	$NH_2^+ + 2O_2 + 2HCO_3^- \dashrightarrow NO_3^- + 2H_2CO_3 + H_2O$

(3)

In plants where insufficient alkalinity buffer is present in the wastewater, this pH depression can drive levels down to a point where the treatment process is significantly impaired. Normally, carbonaceous oxidation can tolerate lower pH levels than nitrifiers. As a general rule of thumb, do not allow your pH values to fluctuate out of a 6.5-8.0 range. Remember, it will commonly require 10 times as much alkalinity as ammonium to achieve complete nitrification. Although approximately 3.75mgs. of alkalinity are returned to the process during denitrification, sever pH depressions can still occur.

Should your pH levels fall too far, you may need to use an artificial alkalinity buffer. Lime and sodium bicarbonate are both useful in elevating pH. and can be used to combat the effects of nitrification.

Temperature is also important in the process control of an Oxidation Ditch. Variations in the temperatures can have a dramatic effect on the activities of a microbial population. As a rule of thumb, the metabolic rate of a bug will double for every 10°C rise in temperature. This means the activity of your aeration zones can vary hundreds of percent, up or down, depending on the way seasonal temperatures swing. Normally, wastewater plants operate at ambient air temperatures. Since this eliminates the possibility of direct temperature control of the system, operations must, instead, control for the effects of temperature. Take for instance a cold climate, as opposed to a warm one, you would expect for your system to take longer to achieve a given level of clarification in the colder region. This is in fact the case. In order to compensate for this loss of efficiency you end up needing more time for the microorganisms to contact the waste. From an operational standpoint this means increasing your MLSS and SRT's, while correspondingly reducing your wasting. Remember even diurnal swings in water temperatures affect your plants kinetic dynamics and place restrains on your operational practices.

In summary, there are several important factors which influence the success of the oxidation process in an extended aeration plant. First, you should control your plant in favor of nitrifying organisms. This will enable the greatest efficiency to occur in both carbonaceous and nitrogen oxidation. Second, you must take care to provide sufficient dissolved oxygen for the support of oxidizing microorganisms needed in the process. By maintaining D.O. levels above 1ppm and by closely monitoring these levels to safeguard against diurnal swings and shock loads, an optimum environment can be sustained for microbial growth -- while at the same time containing costs. Third, a solids detention time (SRT) of at least 7 days must be sustained in order to allow populations of nitrifying bacteria to build-up to useful levels. Fourth, maintenance of a pH above 6.5 is necessary to guard against inhibiting the system; remember that nitirification places a significant demand on alkalinity and can seriously depress pH values. Fifth, the process must be protected against concentrations of toxicants. By communicating effectively with business, metering toxicants slowly into the system, maintaining high MLSS levels, etc., you can reduce the damage which toxic material can have Lastly, be aware of the effects of temperature on your system and base your process control accordingly.

DENITRIFICATION

As mentioned earlier the Oxidation Ditch process has the ability to sustain both an oxygen rich (aerobic) and an oxygen starved (anoxic) environment, without the requirement of two separate systems. By performing this dual function the process can both oxidize material in the aerobic zone and reduce or denitry nitrates in the anoxic zone, all at a substantial cost savings over conventional approaches.

Simply stated, the process of denitrification is where certain types of microorganisms, known as facultative heterotrophs, have the ability to utilize oxygen attached to nitrogen compounds in their metabolic functions. As a result, these microbes can survive and prosper in dissolved oxygen levels too low for aerobic microorganisms. This process of stripping oxygen off of Nitrous Oxide (NO), Nitrite (NO_2^-), and Nitrate (NO_3^-), is called denitrification and is the second step in removing nitrogen from wastewater through biological means. In the following discussion we will be looking at how denitrification in a biological environment occurs. Also, we will study how the operations of the oxidation ditch can be controlled to favor the most effective removal of undesirable nitrogen.

DENITRIFICATION KINETICS

To begin with, a large number of different types of microorganisms are involved in denitrification. Consequently, it becomes unprofitable to look at any one group kinetic

description when trying to understand denitrification. In general, however, there are some basics which nitrogen removal dynamics require. First, the respiratory functions which occur in carbonaceous oxidation are almost identical to those of denitrification. In fact, they are so similar that facultative organisms can switch back and forth between aerobic and anoxic environments rapidly by only changing one enzyme. This ability to alternate rapidly from a free oxygen source to nitrates has a very definite bearing on the operation of the treatment plant. From a strictly chemical standpoint, the facultative microorganism can gain 17% more energy from respirating with free oxygen, as opposed to stripping nitrates. It has been calculated that 686 kilocalories of energy are liberated per mole of glucose oxidized in the presence of free oxygen, as compared with 570 Kilocalories which are obtained from nitrates (5). In each of the two cases organic carbon is used as the electron acceptor, but it is free oxygen, rather than nitrate, which is the more energetic as an electron donor. The consequence to operations is that unless forced, these organisms will invariably seek out the more abundant energy source of free oxygen and abandon any attempts to denitrify.

Fortunately, it is relatively easy to create anoxic zones thru the operation of the Oxidation Ditch process which will force the denitrifiers to make the conversion. Before going on, it is necessary to make a distinction between anoxic

and anaerobic conditions. In the former case oxygen is only severly reduced, whereas in the latter, oxygen has been completely eliminated. The deterioration which an anaerobic environment entails cannot be tolerated in an activated sludge process. The Oxidation Ditch process, by maintaining fluid velocities of 1FPS. can create oxygen-starved areas without allowing the development of anaerobic conditions. To do this, Dr. Pasveer designed the aeration tank in the form of a long race course channel. In this way the respiration of the microorganisms consume all the available free oxygen before reaching the next aerated zone. By spacing the aerator far enough apart, you in effect artifically create alternating zones of relative oxygen abundance and starvation, an ideal set-up for denitrification. By utilizing a dissolved oxygen probe, operators can assess the oxygen profile of the activated sludge zone and manipulate the most beneficial environment for both aerobic and anoxic requirements.

A second area of control concerned with the process of denitrification revolves around the development of optimum levels of organic carbon need by denitrifying organisms as food. From a chemical standpoint carbonaceous material is utilized by the faculative microorganisms to achieve denitrification in a two-step breakdown. This two step sequence is symbolized in the following reaction formulas as:

$$NO_3^- + 0.33\ CH_3OH \underset{\text{(sewage)}}{\overset{\text{(microorganism)}}{\rightleftharpoons}} NO_2 + 0.67\ H_2O$$

$$NO_2^- + 0.5\ CH_3OH \underset{\text{(sewage)}}{\overset{\text{(microorganism)}}{\rightleftharpoons}} 0.5N_2 + 0.5CO_2 + 0.5H_2O + H_2O + OH^-$$

Recognize that this formula portrays the organic carbon source as methyl alcohol which simplifies any intermediate steps. Such a clear-cut breakdown is not the case when sewage is used as a substrata in support of oxidation. What the formula does clearly point out is that whatever substrata is used, in order to achieve complete denitrification, two separate and distinct breakdowns must occur. In process control care must be exercized to promote the most favorable conditions for this complete breakdown.

A major problem which tends to crop up in maintaining populations of facultative microbes, is their relatively delicate nature. The aerobic heterotrophs simply out-compete with denitrifiers in a typical sewage environment. More conventional approaches to denitrification use a separate stage system where low level BOD waste is introduced to a predominately facultative population group. Carbonaceous material or BOD, in the form of alcohol, is reintroduced to the process to provide just enough food to completely reduce nitrogen compounds to nitrogen gas. This kind of refined technique is not possible in the Oxidation Ditch process, as a consequence, the system is inherently less efficient. Offsetting this loss in efficiency is a corresponding cost reduction in construction,

operations and maintenance of the process. In order to promote the most efficient denitrification in an Oxidation Ditch plant current opinion favors a low F/M ratio of between 0.25 to 0.35 with a corresponding high SRT value of between 10-30 days (6). It is a distortion of our present understanding of mixed media denitrification to say that by setting up procedures X, Y, and Z you will invariably obtain good results. The truth of the matter finds operations working somewhere in the region between a guess and science. Once you have provided the gross environmental conditions of anoxic zones, a pH between 6-8, carbonaceous substrata, a ball park SRT and F/M ratio, etc., you, of necessity, base your operational techniques on how the system responds. In the final analysis it is the efficiency of the process which dictates the guidelines by which you operate the process. Any other approach involving the multi-variables of an Oxidation Ditch plant has no meaning.

HELPFUL HINTS IN THE OPERATIONAL CONTROL OF AN OXIDATION DITCH

Having now read about carbonaceous oxidation, nitrification and denitrification, the next logical question to ask yourself is "how do I operate my plant". In this section of the module we will attempt to cross the gap between the conceptual understanding of the plant processes and some of the routine operational realities which make it possible to

run a system continuously. Perhaps the thought of performing a routine each day lacks somewhat in glamor and excitement but it more than pays for itself in the quality of the plant's final effluent. One area which requires constant attention is general upkeep and housecleaning of the plant. At first glance the appearance of the plant wouldn't seem to be something which would affect the quality of the effluent. However, there are some very sound and practical reasons why keeping the appearance of the plant neat does affect the operations of the plant. Of course, the real reason you keep your work area orderly is to prevent yourself from injuring a valued part of your body. It is each individual's responsibility to guard against accidents to themselves and others. One of the most common hazards in sewage treatment is a cluttered up work environment. Probably the two most worthless things to say after an accident are "I should have" or "I'm sorry," just a minimum of housecleaning can substantially reduce the possibility of ever finding those words on your lips. Another very tangible result of a neat plant is the positive public relations which it can incur. Very seldom are the sentiments of the public aroused more by marginal quality effluent than by a shabby looking plant. Although sad it is true that the quality and efficiency of the treatment plant is measured directly by the public through the length of the grass. Aside from the aesthetic considerations, a good housekeeping routine can have a direc bearing on the quality

of your final effluent. Take the case where routine cleaning of the Secondary Clarifier launders is neglected. As the amount of algae and debris builds up, the V notch will begin to plug. The results can ultimately develop into a short circuited flow pattern, ineffective clarifier and an upset plant.

Another area of concern in clarification revolves around the cleaning of draft tubes in the secondary clarifier. Draft tubes work in accordance to a relatively small difference between the surface of the clarifier and the level of the center well. As a result, draft tends to be prone to clogging and must be checked on a regular basis. Unless the tubes are clean and flowing freely, solids will accumulate in the bottom of the secondary clarifi - instead of circulating back to the areation zone in in a timely manner. Here these solids can stagnate, becoming hard to settle, odorous, and less effective in the treatment process once returned. By routinely watching the operation of the draft tubes it is possible to improve the efficiency of your entire system. As a parenthetic note, while you are out checking the draft tubes it is always a good idea to make sure the rake arm assembly is working properly. This is in no way besmirching of one's intellect for being mentioned, because the center mechanism turns so slowly, it is rather difficult to tell if it is moving. It is not at all an uncommon occurrence for

a person to thoroughly clean the draft tubes and then return later to a clarifier full of the real thing and the rake arm stopped in one position.

Mentioned earlier in passing, the routine development of an oxygen profile in your aeration zone can be a valuable operational asset. The concern with such a profile stems from the nasty tendency of dissolved oxygen to disappear toward the bottom of your activated sludge channel. By performing a cross-sectional survey of the dissolved oxygen levels, you will protect the activated sludge from the potential of a dead mixing zone and a resultant anaerobic environment. Such areas of slow mixing and depressed oxygen levels can cause increased filamentous growth, undesirable odors, a deterioration in the effectiveness of aerobic microorganisma, etc., and should ' guarded against with the judicious use of a D.O. probe.

Unquestionably, the most useful and versatile instruments in assessing the effectiveness of plant performance and maintenance of a functional system are the operators themselves. An experienced operator can provide an intuitive insight into the operation of a plant which is impossible to duplicate in the laboratory. In order to provide a truly effective operational environment there must be an intermarriage between the testable and reproducible data of the laboratory and the perceptions which experience brings. Operator in a very real sense becomes attuned to how a plant works and variations in

familiar odors, the color and texture of the sludge, the thickness of a scum layer, effluent turbidity, floc formation characteristics, etc., can all be indications of impending process failure (or recovery). One must develop an awareness of the non-quantifiable data which the senses provide and integrate it into useful tools to regulate plant effectiveness. At the very best operation of any activated sludge system is an attempt to gauge tomorrow's performance on the basis of yesterday's data. The knowledge which you gain from observation and study of the system as it goes through periods of change will provide a foundation for more effective operational decisions. It is your responsibility as an operator to create an awareness of the treatment plant which will help you to find and correct problems before they have a major impact on the system. Without a doubt the most important thing for an operator to remember is to use common sense in dealing with the routine duties of a treatment plant. You are working in a potentially very hazardous environment, subject to injury and contamination from a number of sources. By maintaining an awareness of your surroundings you will substantially improve your operational effectiveness and save yourself from some nasty situations.

OXIDATION DITCHES

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OXIDATION DITCHES

Name ______________________

Worksheet

1. Calculate the volume of an oxidation ditch which has a cross-section as shown below and is 350 feet around in the center of the basin.

2. Calculate the aeration time for an oxidation ditch which has a volume of 0.33 Mgal and an influent flow of 260 gpm.

3. If a float in an oxidation ditch travels 50 ft in 38 sec, what is the horizontal velocity in feet per second?

4. Calculate the F/M ratio for an oxidation ditch which has a volume of 1.0 Mgal with MLSS of 5000 mg/l loaded with a flow of 10 MGD and a BOD of 170 mg/l.

5. If the influent flow is 3 MGD and the RAS flow is 875 gpm what is the percent return flow?